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RFID Technology as Sustaining or Disruptive Innovation: Applications in the Healthcare Industry

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Abstract

In this paper we use the implementation of radio frequency identification (RFID) in various sectors of the healthcare industry as an illustration and application of how academics and managers may assess the potential for new technologies to be sustaining or disruptive to an organization. We review RFID technology, summarize literature related to disruptive innovation, develop a qualitative framework that examines the sustaining and disruptive potential of RFID, and discuss examples of healthcare applications within the context of this framework.

Keywords: RFID, Radio Frequency Identification, Sustaining, Disruptive, Strategy, Innovation, Healthcare

1. Introduction

Understanding and forecasting the effects of new technologies on organizations and industries is of interest to both the business academic community and management. Managers need to understand these effects in order to recognize new opportunities or threats to their business operations. Academics seek to understand the effects in general, in order to develop theories that explain the relationships between technology, strategy, operations and culture. The rise of the personal computer, wireless communication, ATM machines, and the Internet are examples of technologies that have significantly impacted an industry and have been the subject of several studies.

Radio frequency identification (RFID) technology has lately sparked the interest of academics and business. Low-cost RFID tags can be placed on pallets, items, vehicles, or any object that needs to be tracked. Reading this RFID tag begins the process of relaying information to various computer applications and offers the possibility of connecting virtually every device to the Internet. Managers and academics have asked about the possible applications of RFID and its potential impact on a variety markets.

In this paper, we examine the potential impact of RFID on the healthcare industry. Virtually everyone recognizes the need for change to the healthcare industry in the United States. Rising costs, inadequate healthcare coverage and healthcare mistakes have prompted the government to investigate ways to improve this industry. What is the likelihood that RFID could have an impact? What roles could RFID play and how might RFID change the major players in the industry? In this paper, we review RFID technology, summarize literature related to disruptive innovation, develop a qualitative framework that examines the sustaining and disruptive potential of RFID, and discuss example healthcare applications within the context of this framework. The paper concludes with a summary and recommendations for future research.

2. RFID Technology

A RFID tag is a small microchip equipped with an antenna that is often manufactured as an adhesive label (Borriello, 2005). The adhesive label may be placed on a product, box, or pallet. RFID tag readers – placed strategically at various locations such as loading docks, retail store shelves and interstate highways – are able to read the tags using wireless communication and without requiring line of sight. Tag readers interrogate the tags, which transmit their data in response to this interrogation. Tag reads are then processed by computing infrastructure comprised of several layers of software and server hardware (Chalasani, Boppana, and Sounderpandian, 2005).

RFID technology differs from the optical bar code technology on two dimensions: ease with which information may be accessed and the amount of information that may be stored. Bar codes require line of sight communication and most often contain only the type of the item (Eckfeldt, 2005). At the core of the RFID tag is the electronic product code (EPC), which enables the unique identification of an item through storage of its type and serial number. EPC is encoded into the tag's microchip (*The EPCglobal Architecture Framework*, 2007), and even a 96-bit EPC has the ability to uniquely distinguish an item from its billions of "siblings". EPC data in RFID tags can store a significantly larger amount of information compared to bar codes, and the stored information can be changed, dynamically if needed, at different steps in the supply chain.

RFID tags can be either active or passive. Passive tags do not require a power source and are powered by the RF signal sent by the interrogating RFID reader (*The EPCglobal Architecture Framework*, 2007). Active tags contain an embedded power source. Passive tags can only transmit signals over a shorter range and can operate over longer periods of time. Active tags can no longer function once their embedded power source runs out, but can transmit signals over longer distances, up to 100 meters. Active tags also tend to have a higher accuracy of data transmission compared to passive tags.

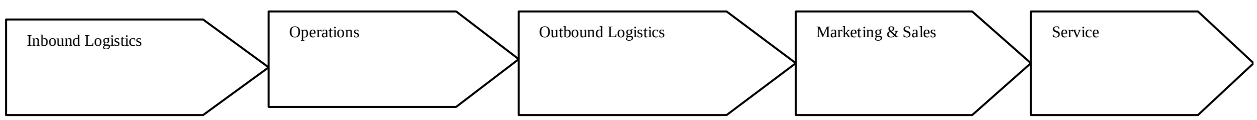
RFID technology has received a significant boost through its adoption by large corporations such as Wal-Mart. The retailer's RFID projects mandate that some of its supply-chain partners adopt the technology in order to comply with Wal-Mart's requirements (Madni, Chalasani, and Boppana, 2007). The U.S. Department of Defense also uses RFID technology, and it has had a similar impact on its suppliers. While some defense applications require active RFID tags, most supply chain applications currently rely on passive tags.

Applications of the RFID technology are ubiquitous. RFID technology on pallets, cases and items can make the supply chain highly visible (Mandviwalla and Asif, 2005). Appropriately designed applications can track the items, cases and pallets on a continuous basis and accurately identify inventory levels, distribution requirements and manufacturing needs in the supply chain. This can make the supply chain "alive" and quickly responsive to events such as an item outage at a retail store shelf, product expiration, or product recall because of government regulation or manufacturing defects

(Sounderpandian, Boppana, Chalasani and Madni, 2007). In business supply chains, RFID technology can facilitate an efficient implementation of concepts such as vendor managed inventory (VMI).

RFID technology is currently used in the pharmaceutical industry to combat drug counterfeiting and on the nation's highways for automated toll-collection without the need to stop the vehicles. Some suggest futuristic applications such as automatic tracking and ordering of grocery items for households that allow their pantry and refrigerators to be monitored by RFID devices. However, for such applications to materialize, significant progress is required in the area of security and privacy.

A very general way to look at the potential impact of a technology is to examine it within the context of a value chain. Michael Porter introduced the generic value chain model in his 1985 book *Competitive Advantage*. Each segment of a value chain has the potential to increase the value of a product in the eyes of a customer. Each segment also contributes to the cost of the product. The five main categories of activities in a firm's value chain are Inbound Logistics, Operations, Outbound Logistics, Marketing Sales, and Service.



The following table indicates possible technology applications that can enhance value or reduce cost for each stage.

Table 1: Technology Applications in a Value Chain

Inbound Logistics	Operations	Outbound Logistics	Marketing & Sales	Service
Technologies related to transportation, materials handling, storage preservation, communication systems, and testing	Technologies related to product development, machine tools, material handling, packaging, and information systems	Technologies related to transportation, material handling, communication systems, and information systems	Technologies related to media, audio and video recording, communication systems, and information systems	Technologies related to diagnostics and testing, communication systems and information systems

RFID technology is capable of impacting all aspects of the value chain, since it is being used in transportation, materials, products, and communication systems. The specifics of the impact of RFID on the value chain differ from industry to industry, however. In the following sections, we examine the possible impacts on healthcare.

3. Technology Impacts: Sustaining Innovations versus Disruptive Innovations

At the most general level, in order for a technology to have an impact on an industry, there must be suppliers willing to develop and sell the technology and customers willing to buy it. In an often cited work, Bower and Christensen (1995) blended the supplier and customer dimensions in their description of sustaining innovations versus disruptive innovations. Sustaining innovations result in performance improvement in technology attributes most valued by the industry's mainstream customers. These improvements may be incremental or breakthrough in nature. The target customers for sustaining innovation are the customers in the mainstream market who are willing to pay for improved performance. Sustaining innovations are advantageous for established companies, since they can improve profit margins by exploiting the existing processes and cost structures; established companies can indeed improve their competitive advantages via sustaining innovation. A simple example of a sustaining innovation is the continued advancement in processing power of Intel's integrated chips.

A disruptive technology or disruptive innovation is a technological innovation that improves a product or service in ways that the market does not expect. A disruptive technology often leads to either lower-priced products or products designed for a different set of consumers. To illustrate, some wireless technologies are considered disruptive. Early wireless phones, though bulky and limited in their usage as car phones during initial stages, have evolved significantly in terms of integration and functionality. Consequently many wireless phone users no longer subscribe to "wired" phone services. When innovations happen in an incremental manner, the well-established companies have an advantage and they can reinforce their dominance and leadership. However, with disruptive innovations, the new entrants to the market can beat the incumbents by commercializing a simpler, more convenient product that sells for less money and appeals to a new or (previously) unattractive set of customers. Two types of disruptive technologies have been identified: new market disruptions and low-end disruptions.

The new market disruptive technologies lead to products that are simpler to use and more affordable to own. That is, a whole new set of customers start purchasing and using the new market disruptive products. Examples of new market disruptive products include the personal computer and Canon's desktop photocopier. Such type of disruption does not invade the mainstream market, but it pulls some customers away from the mainstream market into the new products because they are more convenient to own. Initially, new market disruptions do not pose a threat to well-established companies, since only the low-end customers are pulled away by the new products. However, as the disruptive technologies improve and start replacing the medium- and high-end products, the established companies feel the threat of competition.

In low-end disruptions, there may not be any new customer base (unlike in new market disruptions). The technological products are tailored towards low-end customers of the previously established market. For example, the entry of discount retailers (e.g. Wal-Mart and Kmart) and the entry of Korean car makers are considered low-end disruptions. Low-end disruptions may cause established companies to move away from the low-end markets. Some disruptors are hybrid disruptors and combine the new market and the low-end disruptive models. For example, Southwest airlines lured customers who were not flying as well as some low-end customers from established airlines.

In Bower and Christensen (1995) sustaining innovations are marketed by established or incumbent businesses and disruptive innovation is developed by new entrants into the market. Nault and Vandenbosch (2000) used a slightly different model. In their model both incumbent and new entrants could create disruptive technology. Disruptive technology refers to the package of features and the significant level of impact on the market rather than the establishment of the supplier. The alternatives to disruptive technologies are labeled extensions. An extension is the next generation of an existing product in the form of an incremental change. Incumbent suppliers are more likely to produce an extension and new entrants are more likely to produce a disruptive technology in the Nault and Vandenbosch model.

In order to evaluate RFID’s impact on the healthcare market the attributes of the suppliers and the possible customers need further detail in order to assess whether there is a likely supplier or market for this technology.

4. Sustaining or Disruptive Innovation? Dimensions to Evaluate

The framework we propose for describing and evaluating RFID’s potential impact on healthcare is organized around two fundamental concepts: The potential market and the potential suppliers to that market. First, we ask is there a market for RFID in healthcare and what is the nature of that market? Second, are there suppliers for that market and what are the characteristics of the suppliers? The previously summarized concepts of sustaining versus disruptive and disruptive versus extension are woven into this framework.

4.1. The Dimensions of the Market

Determining the demand for any new market is risky. While some new technologies succeed, others never live up to their predicted potential. However, based on the previously cited literature several general attributes of the market can be examined. These attributes are posed as questions below:

- Will the potential RFID application sustain existing customers through some incremental improvement to the process or will the application represent a significant change? Does the application service the market in an unexpected way?
- If the application supports existing customers, what are the new services that the application offers?
- Will the application support low end customers of the existing market or attract new customers to the market?

In addition to these questions, several other questions are relevant to assessing RFID's impact.

- What is the size of the market for any potential RFID application? Do the customers currently or in the future have the spending power in this market? Is credit readily available?
- Are there alternatives to the RFID application?
- Are there government regulations that will influence the potential market?
- Where does the RFID application fall in the supply chain? Is this a business to business application or a business to consumer application?
- How does the RFID application integrate into other customer processes and requirements? RFID is not a standalone system.
- What are the disruptions RFID may cause for the customers? Will the application require a significant adjustment in behavior or attitudes?

Qualitative answers to these questions will help assess the potential impact from the customer's perspective.

4.2. The Dimensions of Supply

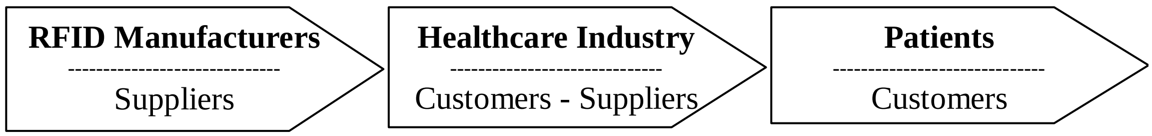
In addition to a possible market for RFID, potential suppliers must be capable and willing to enter the market. The previous cited literature on disruptive innovation suggests some general attributes related to supply.

- Are there existing suppliers that are capable of introducing RFID applications? Do the existing suppliers have the resources, expertise, and business processes required to support RFID applications?
- Are there possible new entrants capable of introducing RFID applications? Do the new entrants have the resources, expertise, and business processes required to support RFID applications?
- Are there incentives to introduce the RFID application (e.g., strong competition in the industry, large profit margin)?

In addition to these questions, the following additional questions appear relevant to assessing the potential suppliers.

- What are the values of the potential suppliers? Are they willing to assume risk? Are they concerned with ethical issues such as privacy?
- What are the costs associated with developing and marketing the new technology. Are the companies likely to take on these costs?
- What are the possibilities for partnerships that can facilitate the research and development process and mitigate risks?
- How different is the technology from current technology already marketed by the supplier?
- Are there government regulations that will influence the desire to introduce the technology or the way the technology is introduced?

In the following sections a variety of RFID applications in healthcare are proposed. These applications are analyzed in terms of these market and supplier frameworks, keeping in mind the following relationships. Manufacturers of RFID technology are suppliers to the various components of the healthcare industry (customers). The healthcare industry itself consists of a chain from hospital/clinic suppliers and consultants (e.g., Abbott, GE Medical, Pfizer) to hospitals. In some cases the hospitals supply RFID technology to the patients/customers.



So while manufacturers and patients will consistently be analyzed as suppliers and customers respectively, the healthcare industry components may take on both customer and supplier characteristics. Sustaining or disruptive characteristics may occur at any point in this chain. RFID manufacturers, for example, may cause disruption in the scanner technology arena. More direct suppliers to the hospitals may supply sustaining or disruptive technology to hospitals, and hospitals may supply sustaining or disruptive technology to the patients.

5. RFID Applications in the Healthcare Industry: Sustaining or Disruptive?

RFID technology has been most widely adopted in the manufacturing and retail sectors, so discussions about RFID as a sustaining or disruptive innovation have tended to look at supply chain applications in those industries (Krotov and Junglas, 2008). RFID technology is also being applied by multiple segments of the healthcare industry, which makes for a richer, more complex environment to analyze. In addition to traditional supply chain and asset management applications, RFID is being used to improve patient care through error reduction, new diagnostic applications, tracking of patients and access to medical information.

5.1. Supply Chain

As with many other organizations, hospitals have implemented RFID into their supply chains to manage and reduce supply costs (Carpenter and Hoppszallern, 2007). While manufacturing and retail supply chains tend to reflect sequential interdependence as outlined by Thompson (1967), where the product of one unit is dependent upon the product received from the prior unit, healthcare reflects sequential, reciprocal and pooled interdependencies. Figure 1, adapted from Chalasani and Boppana (2007), illustrates the concept of sequential interdependence in a retail supply chain with RFID technology. This figure also discusses various events generated by RFID tag-reads in a retail supply chain.

Currently in the retail supply chain, RFID tags are being used at the pallet level. However, it is anticipated that the tags may be applied at the item and case level in the future; especially as the prices for RFID technology is reduced. As an item is manufactured, an RFID tag is placed on the item, which generates the item creation RFID event at the manufacturing facility. Placing an item into a case, placing the case into a pallet as well as loading a pallet into a delivery truck generate different RFID events at the manufacturing facility. At the distributor’s warehouse, placing the pallet into a warehouse shelf, and loading the pallet onto a delivery truck (to be delivered to the retail store) generate RFID events. In a retail store, events such as shelf replenishment, movement of an item from one shelf to another (possibly because of item misplacement) and sale of an item generate RFID events. At the consumer’s home, a futuristic model suggests that the consumer’s refrigerator (or the storage area if the item does not need to be refrigerated) will be equipped with an RFID tag reader. This results in RFID events when an item is placed in the refrigerator and when an item is taken out of the refrigerator. These events may possibly trigger a refrigerator replenishment RFID event.

Sequential interdependence in a healthcare setting would be typified by the supply chain from pharmaceutical companies to distributors to retail pharmacies (including hospitals) to patients. Medical supply chains that transport drugs and/or medical equipment follow the general principles of retail supply chains presented in Figure 1.

Figure 1: Transition of an item from the manufacturer to the consumer in the retail supply chain with sequential interdependence and the relevant RFID events.

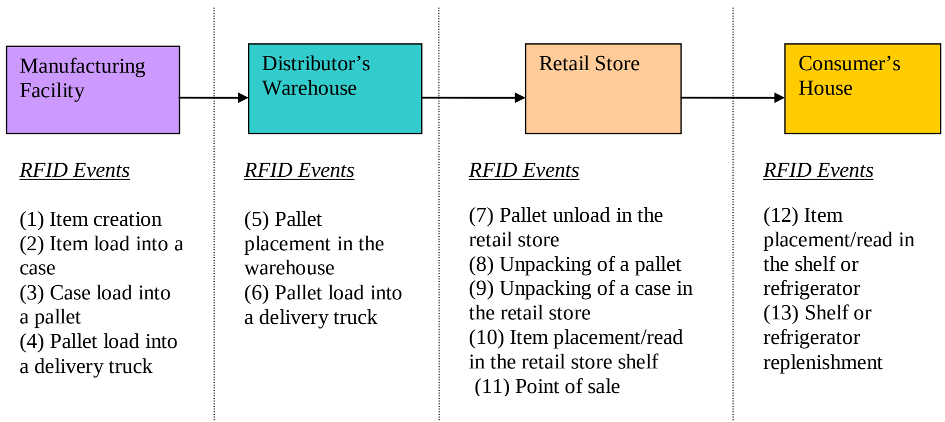
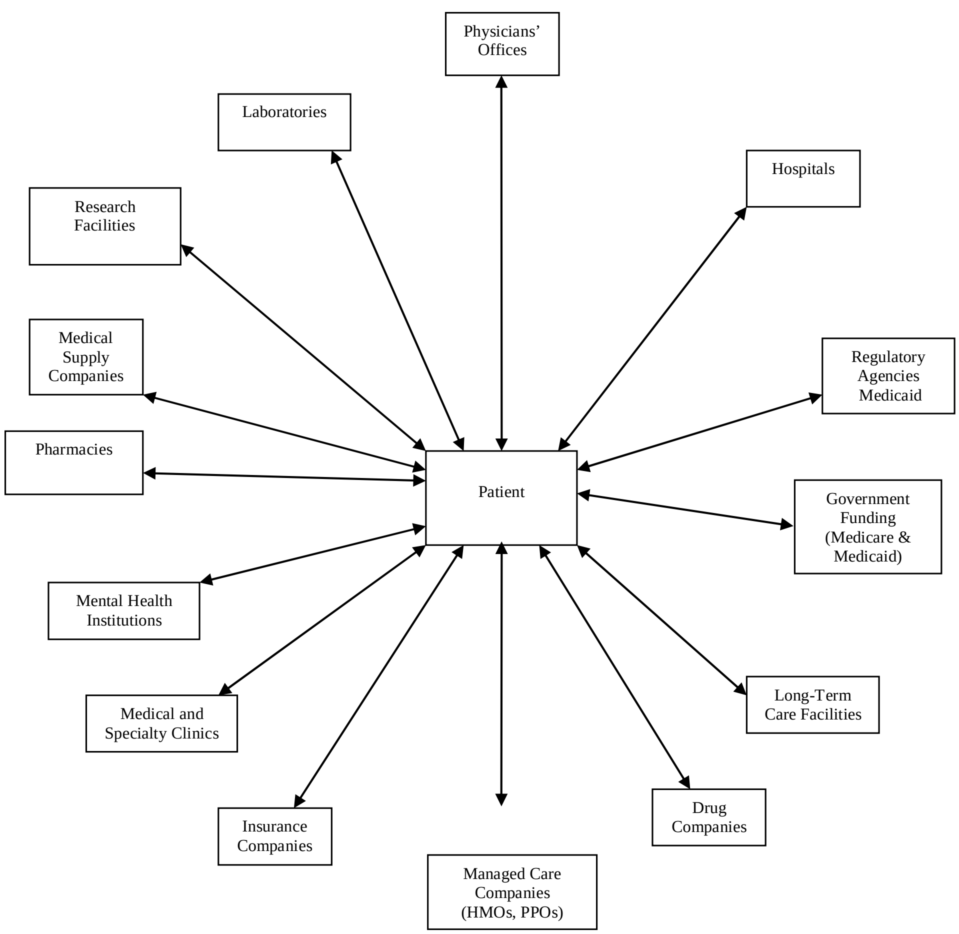


Figure 2: Pooled interdependence for patient care delivery.



With reciprocal interdependence, units can create contingencies for each other that have to be resolved before a product moves on, while pooled interdependence arises when individual units each contribute independently to a centrally located product. That the pharmacy cannot issue blood until it is ordered by surgery, and that surgery cannot proceed until the blood is received from the pharmacy illustrates reciprocal interdependence. Pooled interdependence is evidenced when various departments like the pharmacy, radiology, laboratory, dietetics, and physical therapy each independently provide care to a patient without necessarily coordinating efforts or sharing information. Pooled interdependence is also illustrated at a macro level when various entities collaborate together for patient care as illustrated in Figure 2.

Healthcare systems are inherently complex in nature and address the needs of several stakeholders in healthcare management. Key stakeholders in healthcare industry include patients, physicians, nurses, hospitals, managed care companies, pharmacies, government regulatory & licensing agencies, and government funding agencies as shown in Figure 2.

Managed care companies have become popular in the last decade primarily because of their efforts to contain medical costs. PPOs (Preferred provider organizations) and HMOs (Health Maintenance Organizations) are examples of managed care companies. Managed care companies employ a variety of techniques to contain costs including gate-keeping (requiring mandatory authorization for hospitalization), capitation (payment of a fixed amount per member per month), and generic drug substitution for brand name drugs. A variety of information systems exist within managed care companies to enroll patients, maintain their claim records, audit claims and track physician services.

Hospitals are financed by a variety of sources including payments from managed care companies, Medicare and Medicaid programs. DRGs (Diagnosis related group) payments reimburse the hospitals based on the diagnosis and treatment. Hospital care in the US is characterized by technologies for diagnosis, treatment to electronic maintenance of patient health records.

Groups of physicians often practice together serving patient needs. Physician groups work with managed care companies via insurance contracts, utilize hospitals for in-patient care and work with governmental agencies such as Veteran’s Administration hospitals, Medicare and Medicaid programs. Physicians utilize a number of technologies and information systems to diagnose and monitor patient’s health status. Clinics are utilized by physician groups for treating outpatients. Clinical information systems are utilized for managing patient health records to scheduling patient visits and billing managed care organizations for patient visits.

Governmental agencies provide oversight of physicians, clinics, hospitals and nursing homes. Special units exist for dealing with veterans’ health and for administering programs such as Medicare and Medicaid.

From the above discussion, it is apparent that the interests of key stakeholders translate into myriad business rules that lead to heterogeneity in healthcare delivery and management. A “patient-centric” approach to healthcare delivery requires that at all times the patients’ needs and interests are the focus. Patient-centric healthcare, though simple in concept, is difficult to implement in practice due to the complex nature of reciprocally interdependent systems that govern healthcare in the United States. Healthcare systems exhibit operational and managerial independence. For example, the hospitals and organizations such as HMOs, though they work together, work independently of each other. Similarly, government funding agencies such as Medicare/Medicaid and physicians, hospitals work independently of each other. Healthcare systems are also geographically distributed. It is possible that a patient who resides in Los Angeles needs to be treated in New York or even overseas. In addition, healthcare systems exhibit evolutionary development in the sense that they change continuously in response to government regulation, advances in medical technology, and new threats such as bio-terrorism and the need to cope with large scale catastrophic events.

With regard to RFID’s impact on the sequential supply chain, the initial applications are likely to be classified as sustaining. Most stakeholders in healthcare tend to be established incumbents such as existing hospitals, big pharmaceutical companies, and large medical supply companies. The initial implementers of RFID for supply management have been large hospitals. RFID Venders claim to have a payback period for the investment from about 1 to 2 years (Page, 2007). The initial cost of the RFID application is significant, ruling out early adopters by a low end market. In a recent study, however, 41% of the hospitals surveyed indicated that they were investigating RFID applications; this was the largest percentage compared to any new medical information system technologies (Carpenter and Hoppszallern, 2007). New or proposed government regulations regarding the tracking of and administering of drugs appear to boost RFID interest in the drug supply market (note: California recently passed legislation requiring better tracking). On the downside for RFID, RFID is known to cause significant adjustments in business processes. The paper and pencil method used to keep track of medical supplies in closets, for example, needs to be replaced by inventory monitoring via computer and moving the inventory past an RFID reader. In the case of larger hospitals barcode scanners are being replaced by RFID. In these cases, clearly RFID is sustaining.

Similarly, the supply side points largely to a sustaining technology. Large suppliers like McKesson, Phizer, and GE Medical have developed RFID applications. However, many startups like Mobil Aspects and Awarepoint, have also developed these applications and specialize in RFID consulting. To some extent the larger companies are moving cautiously. RFID does not always work well with liquid drugs and may interfere with some medical equipment. The risk aversion may open some doors for new entrants, though all companies must meet government standards in the health industry. The potential interest by new entrants will likely spur additional interest by established players. For example, GE Medical recently purchased Agility Healthcare solutions, an RFID supplier and consultant.

RFID systems for reciprocal interdependence will likely be created as extensions of the sequential system. Consequently this is also likely to be classified as a supportive technology. On the other hand, pooled supply chains have significant potential as a disruptive technology. The business processes and standardization necessary to integrate these diverse systems is significant and no one supplier currently has the incentive to create this system. This application is discussed in more detail in the electronic medical records section.

5.2. Asset Management

The applications and the players involved with asset management systems are similar to those discussed for the supply chain. Significant benefits have already been realized through use of RFID to track high ticket mobile assets such as defibrillators, ventilators, microscopes, EKGs, and lasers. The tracking of IV infusion pumps is a common asset management application (Birk, 2008). This improves availability, reduces hoarding and theft and therefore replacement costs, and ultimately makes employees' jobs easier and their acceptance more likely (Birk, 2008). These applications would be classified as sustaining innovations, as they are incremental improvements in existing processes on factors typically expected by customers. The demand for these products appears to be growing according to some healthcare surveys. Like the supply chain applications, a mix of large organizations and new entrants are fulfilling demand. However, new entrants are more likely to succeed in the short run in this market because the larger companies are focusing on applications that ultimately trigger a sale.

5.3. Error Reduction

Supply chain applications can also effectively reduce errors in patient treatment. Such dual purpose RFID applications include those used with medications in the pharmacy (Carpenter and Hoppszallern, 2007; Sun, Wang, and Wu, 2008), the blood supply (Trace of Blood, 2008), imaging contrast agents in radiology (Lavine, 2008), and sponges in surgery (Korcok, 2009; Merritt, 2008). In one application, an RFID tag alerts the surgeon when a sponge might accidently be left in the patient. RFID tags have also been used to reduce errors via an application that identifies tissue specimens in gastrointestinal and colorectal surgery endoscopy units (Francis, Prabhakar, and Sanderson, 2009; Korcok, 2009), and making the patient's id wrist band an RFID tag assures proper identification of the individual at all times (Shen, Shih, Chiang and Lin, 2007). Hospitals are interested in the applications for a variety of reasons, including improved patient care, but also reduced possible liability for malpractice suits. These systems also tend to reduce costs due to misplaced items and errors. These improvements in patient care by way of reduced errors would be classified as sustaining innovations, since patients typically expect quality care and hospitals have motive to improve quality.

These ideas may originate through partnerships between academic researchers (e.g., University of Wisconsin-Madison's College of Engineering RFID Laboratory) and segments of the supply chain (e.g., blood banks - Trace of Blood, 2008), and suppliers of the RFID application again are a mixture of incumbent and new entrants. ClearCount Medical Solutions, a maker of RFID-enabled surgical sponges (Korcok, 2009), is a privately held company for whom financial data is not available. Covidien Ltd. (fiscal year 2008 annual revenues of $9.9 billion per Hoover's company records) and Bayer HealthCare Pharmaceuticals Inc. (annual sales of nearly $308 billion in 2008 per Hoover's company records) have developed systems to integrate RFID technology into contrast agents (Lavine, 2008). The Mayo Clinic used an off-the-shelf RFID system from 3M (2008 sales in excess of $25 billion per Hoover's company records), modified for their purposes, to reduce errors in specimen labeling (Francis et al., 2009).

5.4. Diagnostic Tests

Healthcare applications have expanded far beyond the sustaining innovations of tracking of supplies and equipment. Quality of patient care has been improved by incorporating RFID technology into diagnostic tests. One example is the M2A patency capsule endoscopy (Banerjee, Bhargav, Reddy, Gupta, Lakhtakia, Tandan, Rao and Reddy, 2007), where a RFID chip is encapsulated in a biodegradable body and administered to patients to study their intestinal tract. A scanner is used to detect and track progress of the RFID tag through the patient's system. The state of the capsule when it is excreted is used to determine the appropriate next step in treatment. A similar application has been developed to study esophageal reflux (Medical Center, 2007), and a patent is pending for a similarly digestible RFID chip that would track the dissolution of medications within the body (My Weird Project, 2007).

These technological advances in medical diagnostics may originate with academic medical researchers (e.g., Banerjee et al, 2007) or inventors working for companies like Kodak (My Weird Project, 2007). Regardless of their origins, these RFID applications are either reshaping existing markets or creating new ones in the healthcare field and as such would be considered disruptive innovations. The RFID applications would replace existing technology for performing the same procedure.

5.5. Tracking & Monitoring Patients

The intent in the aforementioned processes is for the patient to eliminate the chip from their body at some point during the procedure. This differs dramatically from chips imbedded under the skin or in wrist bands or other accessories designed to track an individual at all times. These tracking applications are implemented more frequently in geriatric (Corchado, Bajo and Abraham, 2008; Niemeijer and Hertogh, 2008) and psychiatric (Huang, Chung, Tsai, Yang and Hsu, 2008; Ucar, Vardar and Kocamaz, 2008) settings and have a by-product of improved facility security (RFID technology can not only track people but prevent them from making unauthorized entry). RFID tags are also being imbedded in dental prosthetics to help identify wearers (Richmond and Pretty, 2009a; Richmond and Pretty, 2009b). While seeming to be a supportive innovation when considering the mission of the organization, such tracking may be deemed an invasion of privacy from a patient/consumer point of view. To illustrate, imbedding a chip in an Alzheimer's patient would allow them to be identified and their medical record accessed immediately regardless of their level of mental acuity (Patient's Dilemma, 2007). Driven by privacy concerns, bioethicists argue that vulnerable populations may be coerced into having the chips imbedded and that the data may be misused for research or commercial purposes (Foster and Jaeger, 2008).

Then again, “telehomecare” (Hsu, Yang, Tsai, Chen and Wu, 2007) offers an example of where context may make a difference in consumer acceptance. RFID as a tracking mechanism may be employed as a component of a monitoring system that has the potential to allow seniors to stay in their homes longer, in lieu of moving into a care center arrangement. The tradeoff of continued independence despite reduced privacy could prove appealing as well as cost effective. So where chips for Alzheimer’s patients may be viewed as a negative innovation because of privacy concerns from the consumer’s perspective, RFID applications that enable independence may be construed in a positive light by consumers.

The size of the market for these tracking and monitoring applications is uncertain. The privacy concerns make this application risky for any business. To date, the applications are primary being developed by new entrants. RFID tag maker VeriChip Corp illustrates the type of company supplying this market (Patient’s Dilemma, 2007; its VeriMed Health Link business had 2008 revenues of $100,000 (Verichip Corporation, 2008). As the population ages, the potential size of this market is huge. Since the market would be new and it is likely developed by a new entrant, this would be classified as disruptive technology from the market perspective.

5.6. Electronic Medical Records

Reforming the U. S. healthcare industry is a high priority for President Barack Obama (The White House, 2009). Included in the American Recovery and Reinvestment Act of 2009, the $787 billion economic stimulus plan, is $19.6 billion to computerize the health system in the form of electronic medical records. The prototype for the nation is being implemented with the military, where active duty records from the Department of Defense and post-retirement records from the Department of Veterans Affairs will be merged into a lifetime electronic health record (The NewsHour, 2009).

Another aspect of military healthcare which has not received as much attention yet is the field electronic medical data-collection device worn by service members. Their medical data is contained on a dog-tag-sized electronic information chip. Medical personnel insert the chip into a hand-carried, palm-sized device for processing and instant updating of the service member’s medical information (Gilmore, 2005). Civilian applications include “smart cards” given to employees at IBM, so that doctors can access their health records during emergencies (Smerd, 2009). Introduction of these applications reshape the existing market and would be disruptive innovations from the customer’s point of view.

While RFID technology currently lacks sufficient capacity to provide portable storage for an individual’s complete medical history, the development of such an application would have an advantage over that of smart cards, given the ability to centralize patient’s medical information for access by multiple entities shown in Figure 2. Figure 3 indicates a way to access patient’s medical information using RFID tag.

Processing of requests for electronic medical records using RFID tags is shown in Figure 3. To address security and privacy concerns, patient’s medical records and patient’s demographic information are separated and stored at different servers. Once the RFID reader reads the patient’s tag, the tag together with the ID of the RFID reader, are sent to the host computer system, which is at the system at the medical facility that the patient visits (Step 1 of Figure 3A). The host computer system then requests an object naming server (ONS server) to translate the RFID tag into patient demographic information (Step 2). The host computer system may need a secure login id and password to access the ONS server. In other words, only requests from recognized host computers are handled by the ONS server. The ONS server accepts a tag as the input and finds out the patient’s details such as the date of birth, name, address etc. This information is transmitted back to the host computer system (Step 3). The host computer system then sends the RFID tag information to the medical records server to obtain patient’s health records electronically (Step 4). The details of when the electronic medical records were obtained by whom is written to the RFID transaction data server (Step 5). The host computer combines the information obtained in Step 2 and Step 4 into the patient's medical information report. The model depicted in Figure 3 is applicable to all locations in the healthcare setting indicated in Figure 2.

It remains to be seen which companies will emerge as the major suppliers for these records systems. Given the scale of this undertaking, one would expect that it would require significant resources for a company to be able to participate. The millions of dollars in government backing is not only attracting the interest of traditional hospital suppliers like Cerner or hospital information technology suppliers like McKesson but also new entrants like General Electric, Intel, and IBM. Partnerships are also being formed to focus on specific segments, with Microsoft and Google partnering to create patient access via the web and Wal-Mart and Dell working together on a physician application that would be sold through Sam's Clubs (Terhune, Epstein and Arnst, 2009). Consequently from both the supply and demand side, this is a disruptive technology.

6. Other Considerations

Regardless of application there are two other considerations that will influence RFID's introduction into healthcare: Privacy and Interference.

6.1. Privacy

As mentioned above, privacy questions figure prominently in discussions of RFID technology applications in healthcare (Foster and Jaeger, 2008; Kohno, 2008; Levine, Adida, Mandl, Kohane, and Halamka, 2007). Might vulnerable populations (e.g., geriatric and psychiatric patients) be coerced? May data be accessed and used in inappropriate ways? The potential for invasion of privacy has been illustrated by inappropriate access to and publication of celebrity medical records, including those of Nadya Suleman, the octuplets' mom (Vijayan, 2009b). Kaiser Permanente fired 15 hospital workers for snooping in her electronic health file.

Patients sensitive to privacy issues are particularly likely to consider the tracking/monitoring and medical records applications as invasive and consequently disruptive to them as consumers. This brings up the interesting question of positive versus negative disruptions. To this point in the discussion there has been an underlying assumption that disruptive innovations ultimately result in positive outcomes for suppliers who seize the new opportunity. For the healthcare industry as a whole, the ability to keep track of patients and medical records more efficiently is a positive disruptive innovation. However, if there is a backlash from patients disturbed by a perceived negative disruption (say they transfer to small providers who stay outside the larger system or threaten lawsuits), at what point does that positive disruption become negative to a supplier?

Given the concerns about privacy, the adoption of electronic medical records and other tracking applications will slowed by privacy laws (U.Va. professor, 2009; Vijayan, 2009a). The Health Insurance Portability and Accountability Act (HIPAA), enacted by Congress in 1996, mandates privacy protection of patient medical data, and individual states have enacted even stronger protections. The stimulus bill includes strict new protections, including a ban on the sale of personal health information, but it is too early to tell how they will be implemented effectively (Hall, 2009). The model depicted in Figure 3 for accessing health information electronically addresses the privacy concerns to a certain extent, by separating the patient's demographic information and the patient's health records. However, this or a similar model still needs to be developed and tested.

6.2. Radio Frequency Interference

Regardless of the foregoing arguments about RFID as supportive or disruptive innovation in various applications in healthcare settings, there is one consideration that opens up the possibility for new entrants to introduce disruptive innovation. Current RFID technology frequently interferes with other medical technologies. A 2008 study conducted in The Netherlands was the first to consider the problem of electromagnetic interference by RFID tags on other medical devices (van der Togt, van Lieshout, Hensbrock, Beinat, Binnekade, and Bakker, 2008). After testing 2 different RFID systems against 41 different medical devices, the researchers found 34 incidents of interference in 123 tests. Despite limitations inherent in the study, the U. S. Food and Drug Administration, manufacturers, and healthcare providers are investigating the problem further (DiConsiglio, 2008; Joch, 2008), and an organization could impact the market significantly by solving the interference problem.

Summary

In this paper the use of RFID as a disruptive or sustaining technology in a variety of applications was explored. A framework was introduced that helped to assess the possible impact and classify the application as disruptive or sustaining within a complex environment. The framework looked at the application from both the demand and supply point of view. Table 2 provides a snapshot of what was discussed in the paper. It illustrates how many different factors determine whether or not an innovation is sustaining or disruptive, provides as summary of general tendencies, and illustrates the complexity inherent in making a determination whether an innovation is sustaining or disruptive. In the healthcare industry, applications that help to manage the assets and the traditional supply chain are seen as sustaining applications, because they tend to improve the existing processes for mainstream customers (i.e., large hospitals). Suppliers for these systems include both large scale hospital suppliers and new RFID consultants. Diagnostic tests, patient tracking and monitoring applications and the electronic medical records system are seen as disruptive because they help establish new markets.

Future research could further investigate the model. A more detailed analysis of a particular RFID application and case studies including the perspectives of potential suppliers, healthcare providers and patients would provide further insight into the motives and success requirements for disruptive and innovative applications.

Figure 3: Processing of Requests for Patient's Electronic Medical Records.

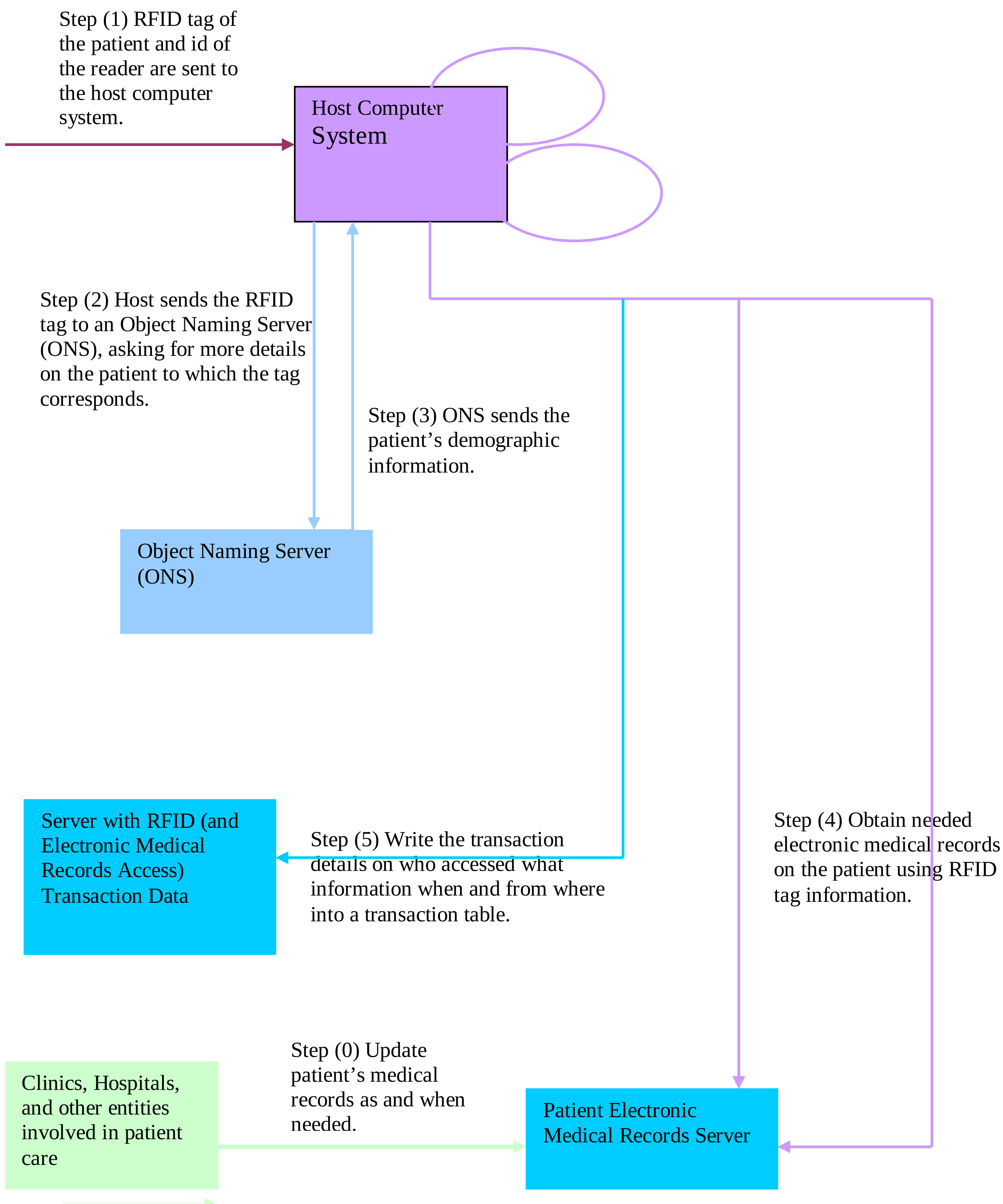


Table 2: Summary of Sustaining and Disruptive Innovations in the Healthcare Industry

	5.1 Supply Chain	**5.2 Asset Management**	**5.3 Error Reduction**	**5.4 Diagnostic Tests**	**5.5 Tracking & Monitoring Patients**	**5.6 Electronic Medical Records**
4.1 The Dimensions of the Market						
Will the potential RFID application sustain existing customers through some incremental improvement to the process or will the application represent a significant change? Does the application service the market in an unexpected way?	S	S	S	D	D	D
If the application supports existing customers, what are the new services that the application offers?	S	S	S	D	D	D
Will the application support low end customers of the existing market or attract new customers to the market?	S	S	S	D	D	D
What is the size of the market for any potential RFID application? Do the customers currently or in the future have the spending power in this market? Is credit readily available?	Potential for all hospitals (large hospitals first) S	Potential for all hospitals (large hospitals first) S	Leading edge hospitals first S	Leading edge hospitals first S	Specialized services D	D
Are there alternatives to the RFID application?	yes	yes	Yes	yes	yes	yes
Are there government regulations that will influence the potential market?	yes, similar to other systems S	yes, similar to other systems S	yes, similar to other systems S	Yes, similar to other systems S	Yes, but some new issues D	Yes, but some new issues D
Where does the RFID application fall in the supply chain? Is this a business to business application or a business to consumer application?	B2B	B2B	B2B	B2C	B2C	B2B and B2C
How does the RFID application integrate into other customer processes and requirements? RFID is not a standalone system.	Integration required	Integration required				D, but requires significant with other new systems
What are the disruptions RFID may cause for the customers? Will the application require a significant adjustment in behavior or attitudes?	S	S	S	S	D	D
4.2 The Dimensions of Supply						
Are there existing suppliers that are capable of introducing RFID applications? Do the existing suppliers have the resources, expertise, and business processes required to support RFID applications?	S	S	S			S
Are there possible new entrants capable of introducing RFID applications? Do the new entrants have the resources, expertise, and business processes required to support RFID applications?				D	D	D
Are there incentives to introduce the RFID application (e.g.,	S	S	S			D

strong competition in the industry, large profit margin)?						
What are the values of the potential suppliers? Are they willing to assume risk? Are they concerned with ethical issues such as privacy?				D	D	D
What are the costs associated with developing and marketing the new technology. Are the companies likely to take on these costs?	S	S	S			D
What are the possibilities for partnerships that can facilitate the research and development process and mitigate risks						D
How different is the technology from current technology already marketed by the supplier?	S	S		D	D	D
Are there government regulations that will influence the desire to introduce the technology or the way the technology is introduced?						D
Legend: S = Sustaining Innovation, D = Disruptive Innovation, B2B = Business to Business, B2C = Business to Consumer						

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